EVALUATION OF A LIQUID DESICCANT AIR CONDITIONING SYSTEM WITH SOLAR THERMAL REGENERATION

Stephen J. Harrison, Ph.D., P.Eng.
Solar Calorimetry Laboratory
Queen's University
Kingston, Canada

Overview

- Main focus of Canadian government is combined heating and cooling systems
- Liquid Desiccant systems are being primarily evaluated
- Two LD systems: AIL LD prototype system and an Advantix DuCool air conditioning & dehumidification.
- Other systems operating in Canada, e.g., conventional absorption (*EnerWorks*) and large scale *ClimateWell* system.

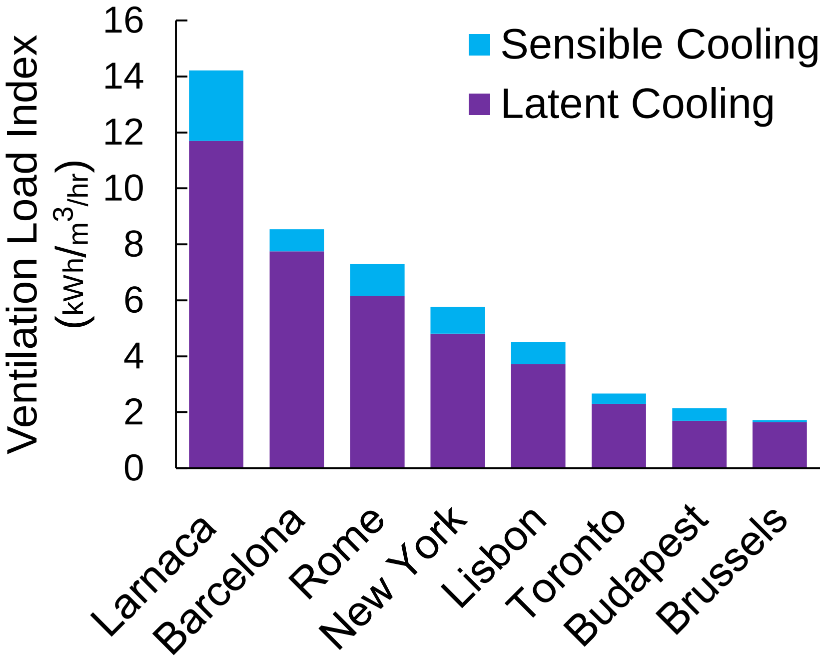
Project Overview

Liquid desiccant air conditioning (LDAC) demonstration project

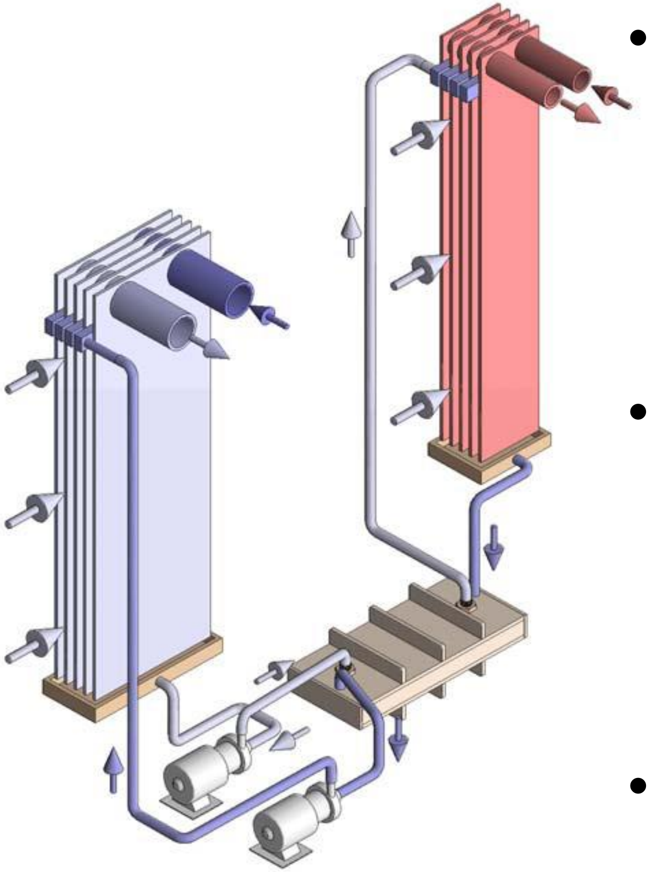
- Phase I (completed):
  - Used gas fired boiler to simulate solar input and drive LDAC
  - Characterized and modelled LDAC performance
- Phase II (in progress):
  - Installed evacuated tube solar array to drive LDAC
  - Will test different configurations and compare with simulation results
- Phase III (beginning)
  - Investigate methods to increase electrical COP
  - Investigate additional desiccant storage
  - Investigate optimal configurations and control schemes

Background

- Solar availability matched closely with cooling load
- LDAC applicable in Dedicated Outdoor Air System (DOAS)
- Designed to handle latent load
- Pair with evaporative cooler or small vapour compression system to handle sensible load
- Ensure adequate dehumidification and provide better control over humidity



EVALUATION OF A LIQUID DESICCANT AIR CONDITIONING SYSTEM WITH SOLAR THERMAL REGENERATION



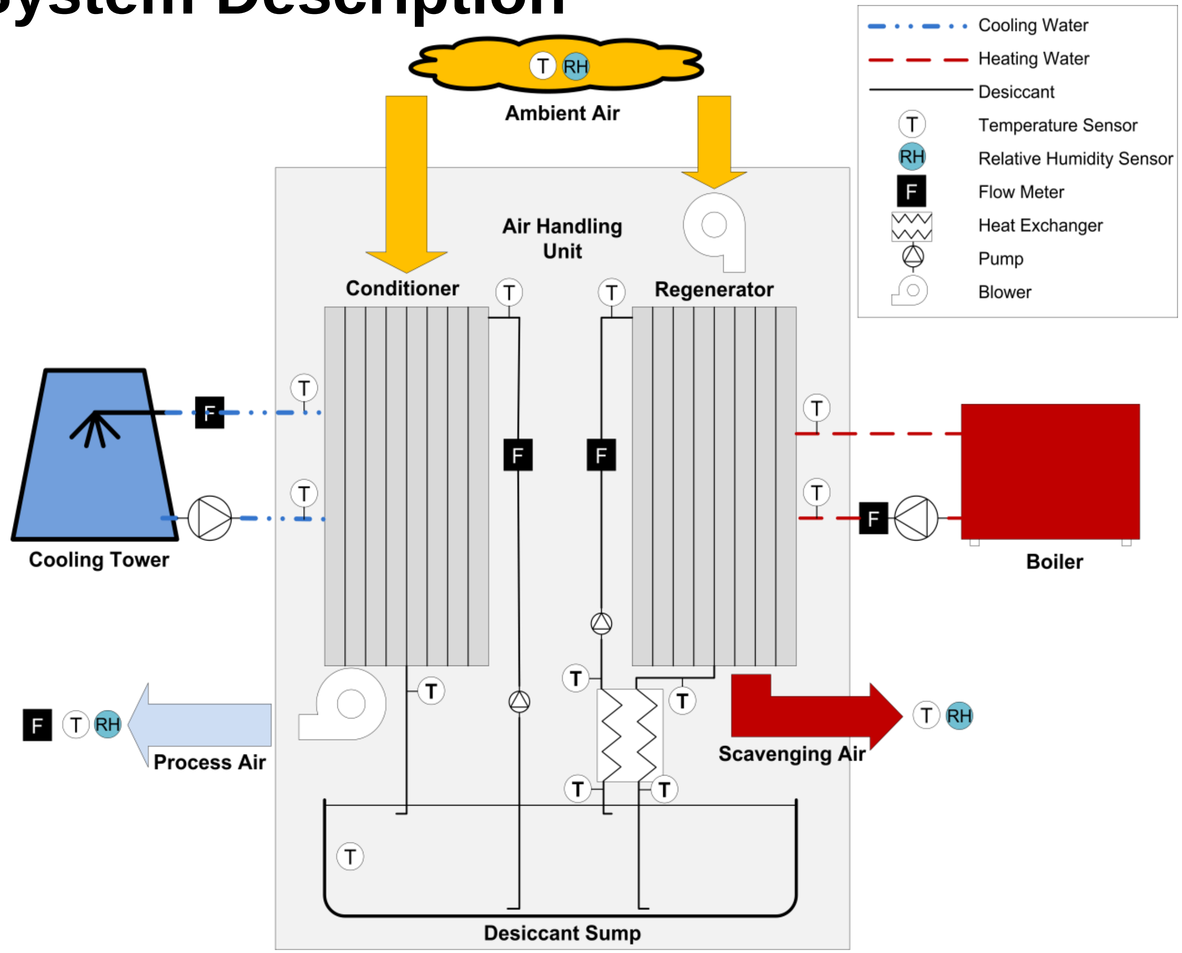
- Conditioner
  - Strong desiccant absorbs moisture from process air
  - Cooling water removes latent heat of condensation
- Regenerator
  - Heating water added to re-concentrate desiccant
  - Moisture in dilute desiccant desorbed to scavenging air stream
- Novel low flow configuration eliminates carry over, increases storage capacity

Source: Lowenstein, A., Slayzak, S, and Kozubal, E. (2007). "A Zero Carryover Liquid-Desiccant Air Conditioner for Solar Applications," 2006 International Solar Energy Conference, ISEC2006, American Society of Mechanical Engineers, pp. 397-407.

LDAC Benefits

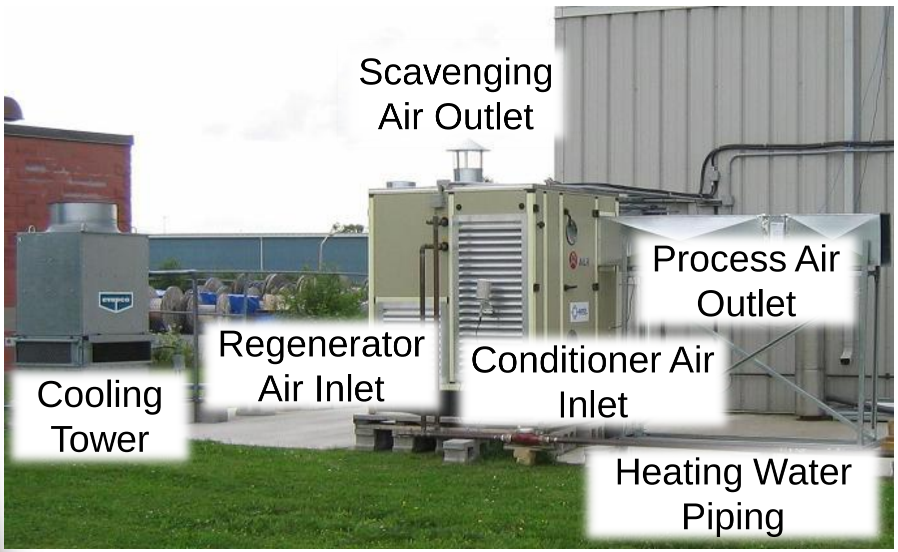
- Dehumidification without over-cool reheat
- Low temp (60-90ºC) heat for regeneration, ideal for solar
- Loss-less energy storage

LDAC System Description



Source: Jones, B.M. (2008). "Field Evaluation and Analysis of a Liquid Desiccant Air Handling System," M.Sc. Thesis, Queen's University, Kingston, Ontario, Canada.

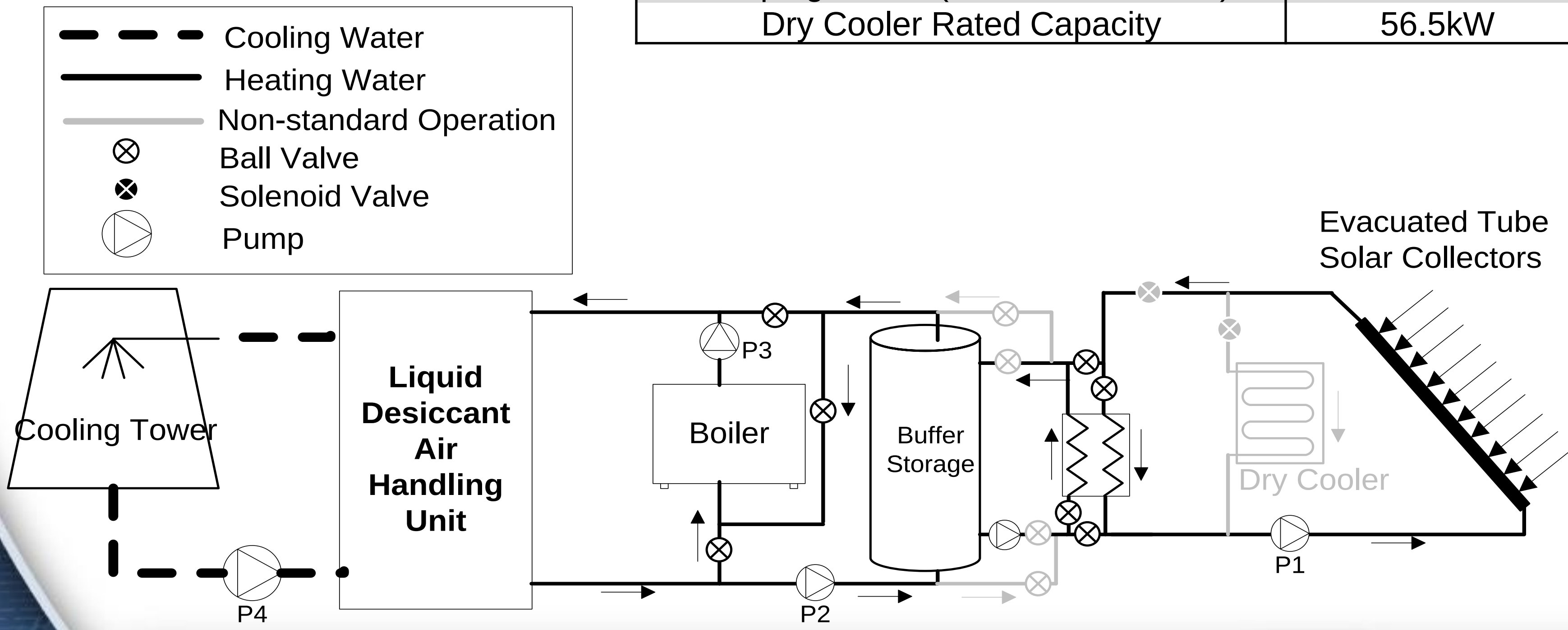
System Operation



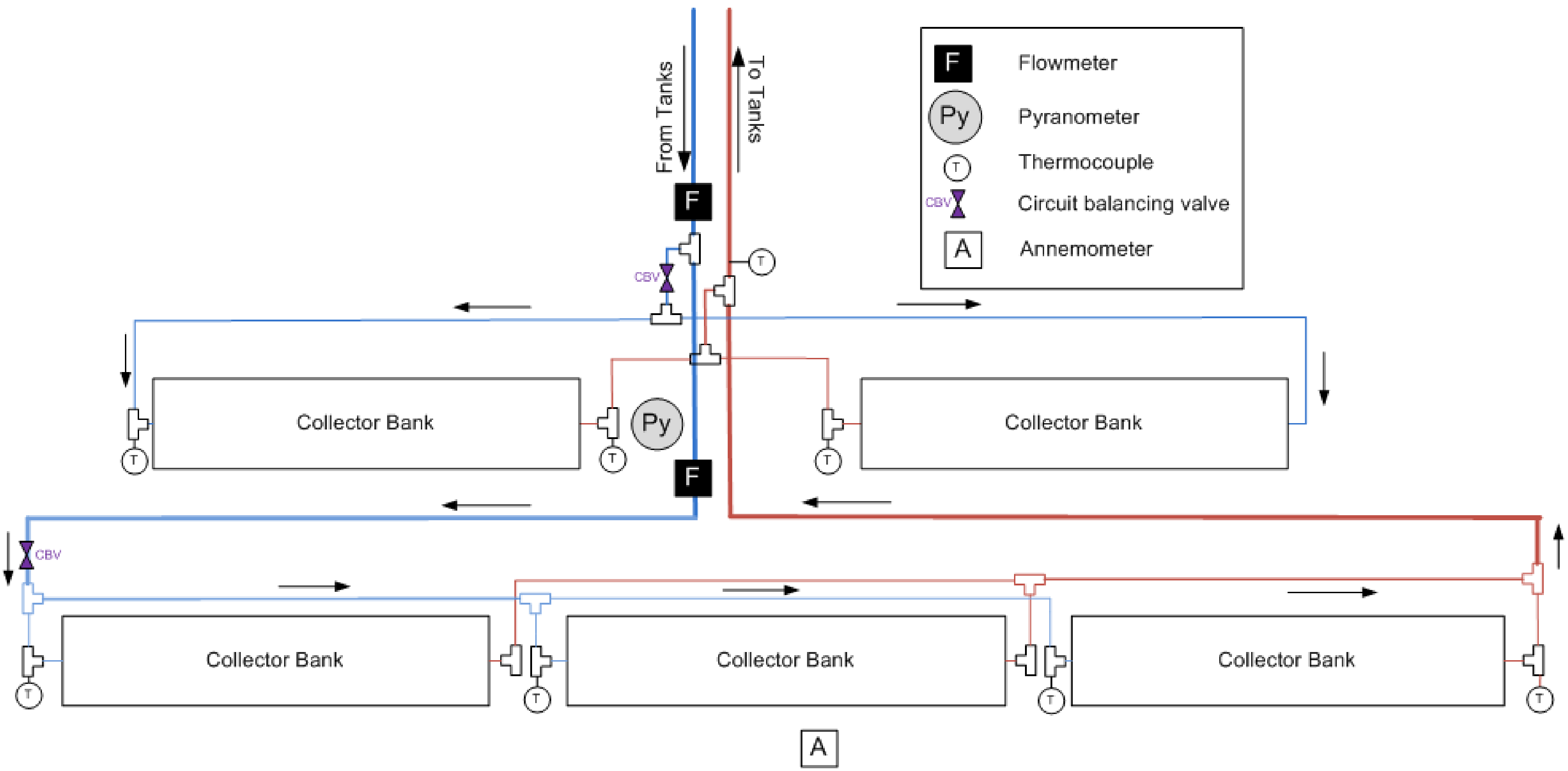
System Parameter	Results
Process Air Flow	1200 L/s
Hot Water Flow	90 L/min
Cold Water Flow	130 L/min
Desiccant Concentration	25.64-42.73 wt%
Conditioner Desiccant Flow	5.3 L/min
Regenerator Desiccant Flow	6.5 L/min
Regeneration Thermal COP	0.419 – 0.761
Heating Water Temperature	50 - 90°C
Measured Latent Cooling Capacity	4.5 – 23.3 kW (1.3 – 6.6 tons)
Measured Total Cooling Capacity	4.8 – 18.1 kW (1.4 – 5.1 tons)

Solar Array Description

Parameter	Design Value
Design Temperature Rise	10ºC
Total Collector flow rate	40-50 L/min
Collector Absorber Area	61m^2
Buffer Storage Size	870L
Pumping Power (collector circulator)	25-450W
Dry Cooler Rated Capacity	56.5kW

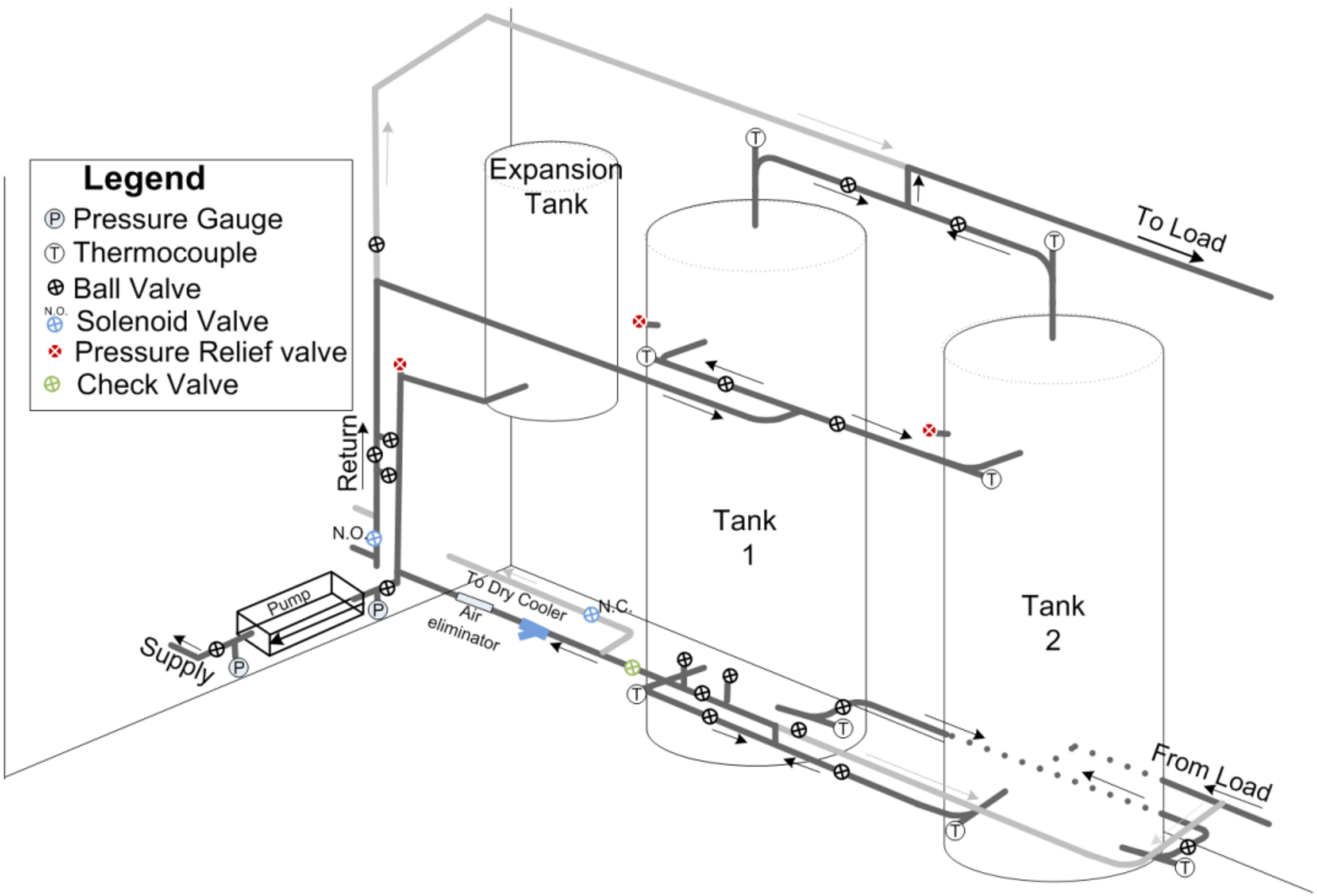


EVALUATION OF A LIQUID DESICCANT AIR CONDITIONING SYSTEM WITH SOLAR THERMAL REGENERATION




QUEEN'S UNIVERSITY

EVALUATION OF A LIQUID DESICCANT AIR CONDITIONING SYSTEM WITH SOLAR THERMAL REGENERATION

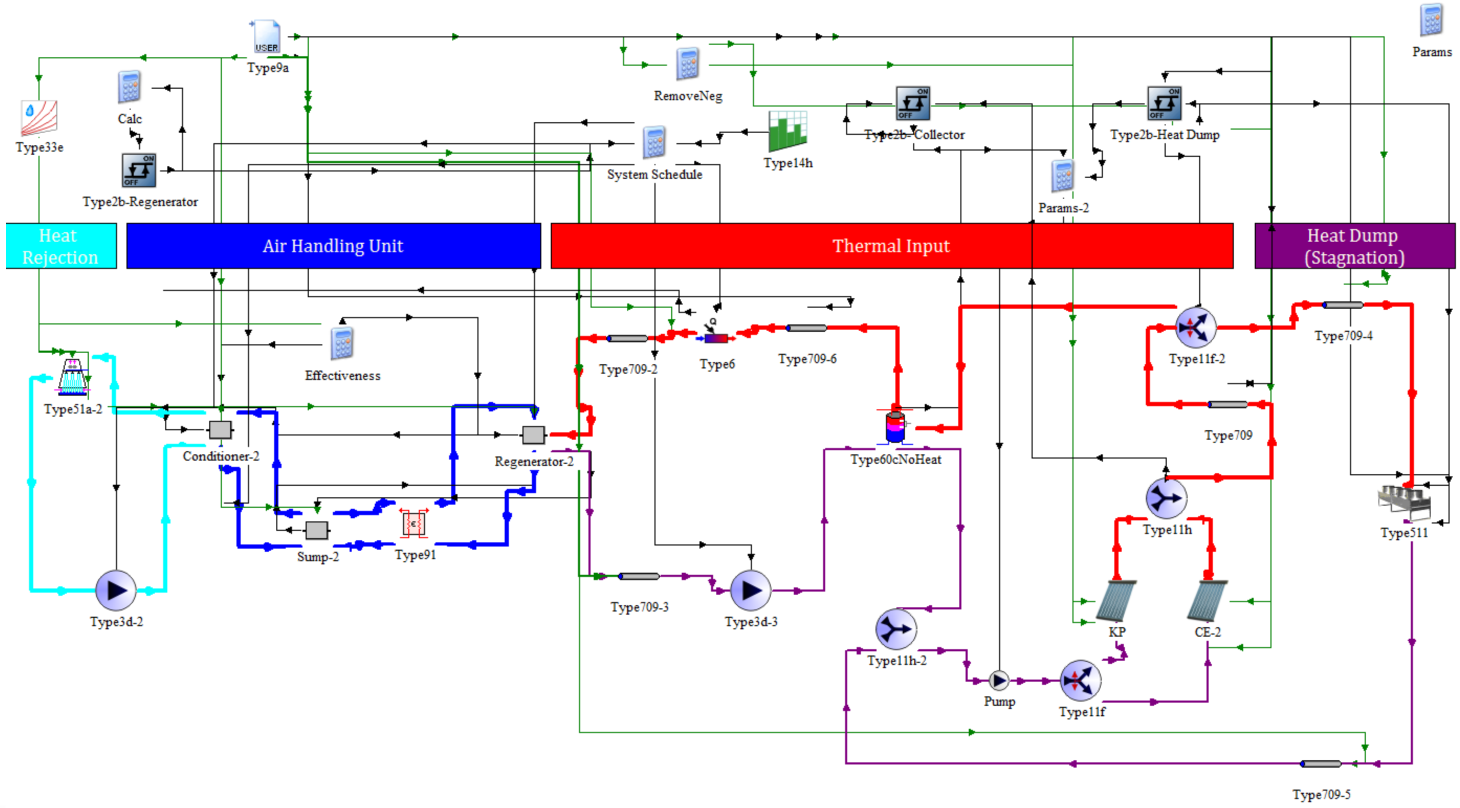


EVALUATION OF A LIQUID DESICCANT AIR CONDITIONING SYSTEM WITH SOLAR THERMAL REGENERATION

EVALUATION OF A LIQUID DESICCANT AIR CONDITIONING SYSTEM WITH SOLAR THERMAL REGENERATION

System Performance, Characterization and Modelling

- TRaNsient SYstem Simulation program (TRNSYS)



Thermal COP $$COP_T = \frac{Q_{Cooling}}{Q_{heat,in}}$$

Electrical COP $$COP_E = \frac{Q_{Cooling}}{W_{elec,in}}$$

Regenerator COP $$COP_R = \frac{Q_{Desorption}}{Q_{heat,in}}$$

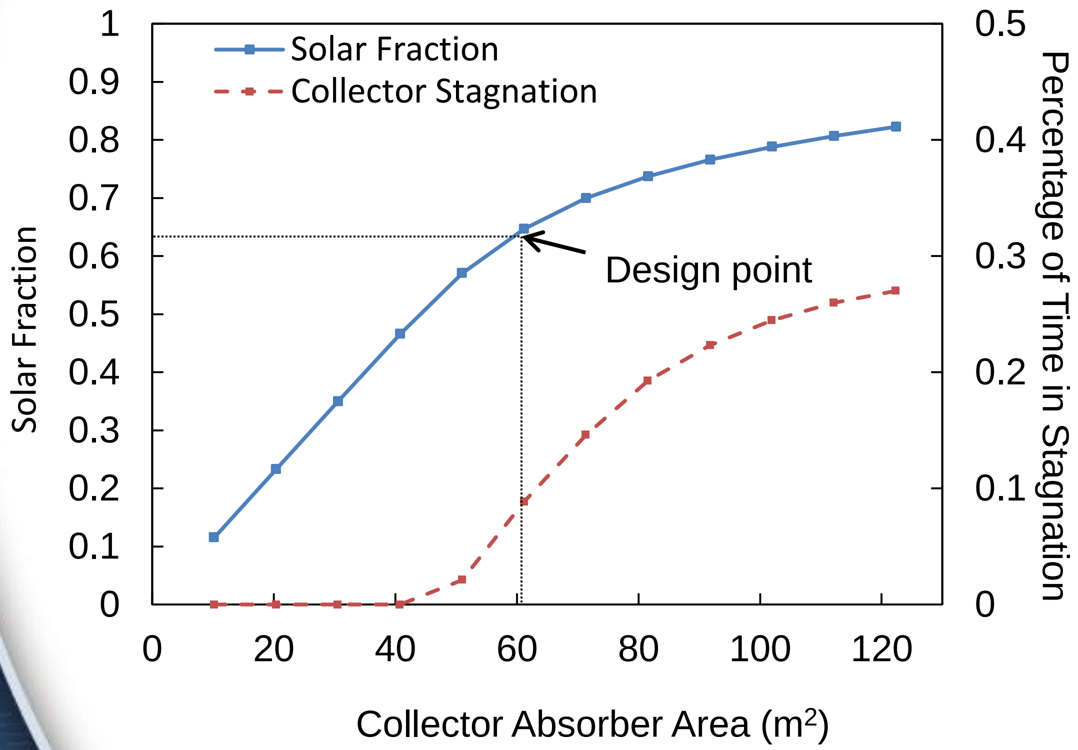
LDAC Performance

Collector Efficiency $$\eta_{Coll.} = \frac{\dot{m} c_p \Delta T}{A_{coll} I_T}$$

Solar Fraction $$SF = 1 - \frac{Q_{aux}}{Q_{load}}$$

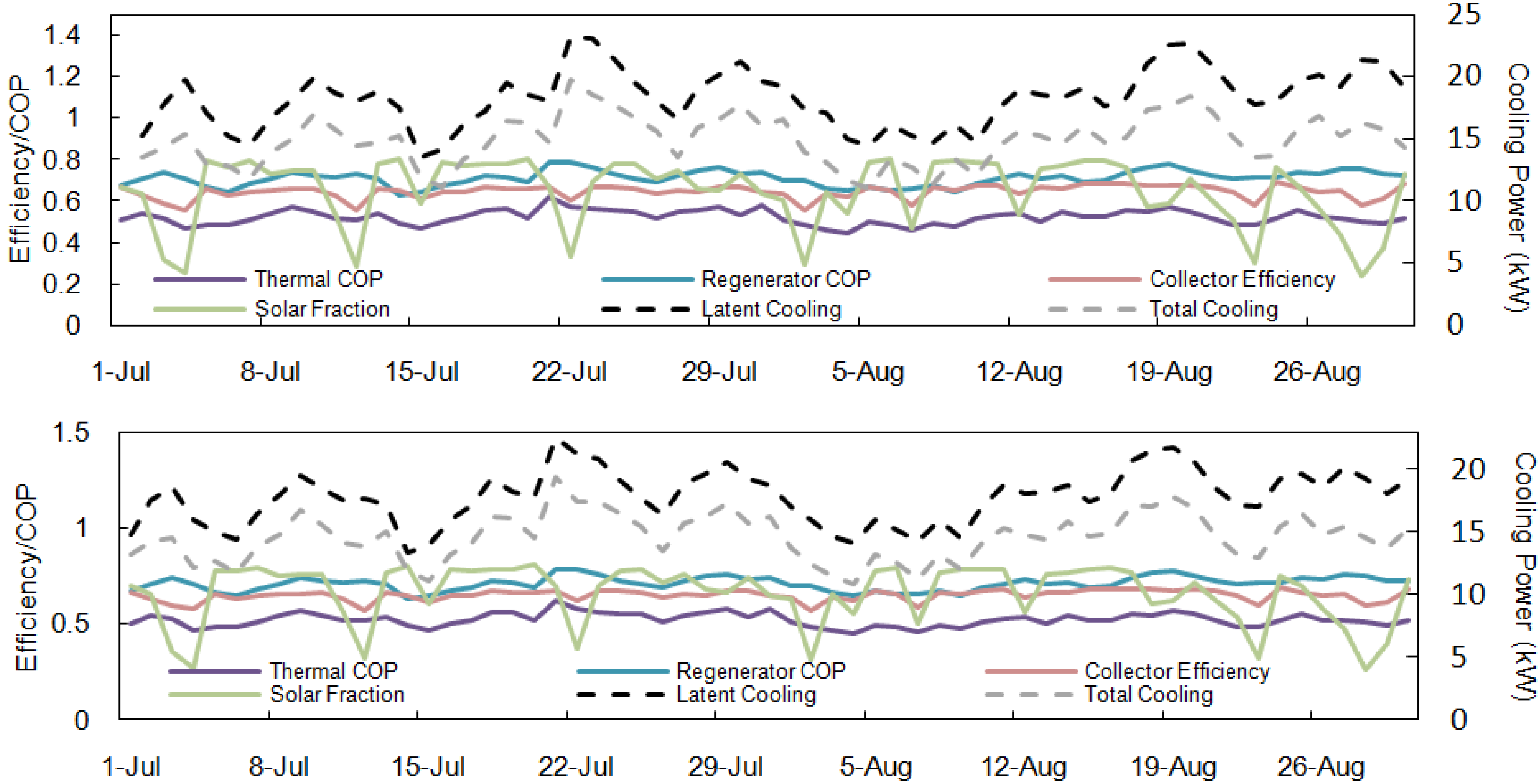
Solar Performance

Simulation Results

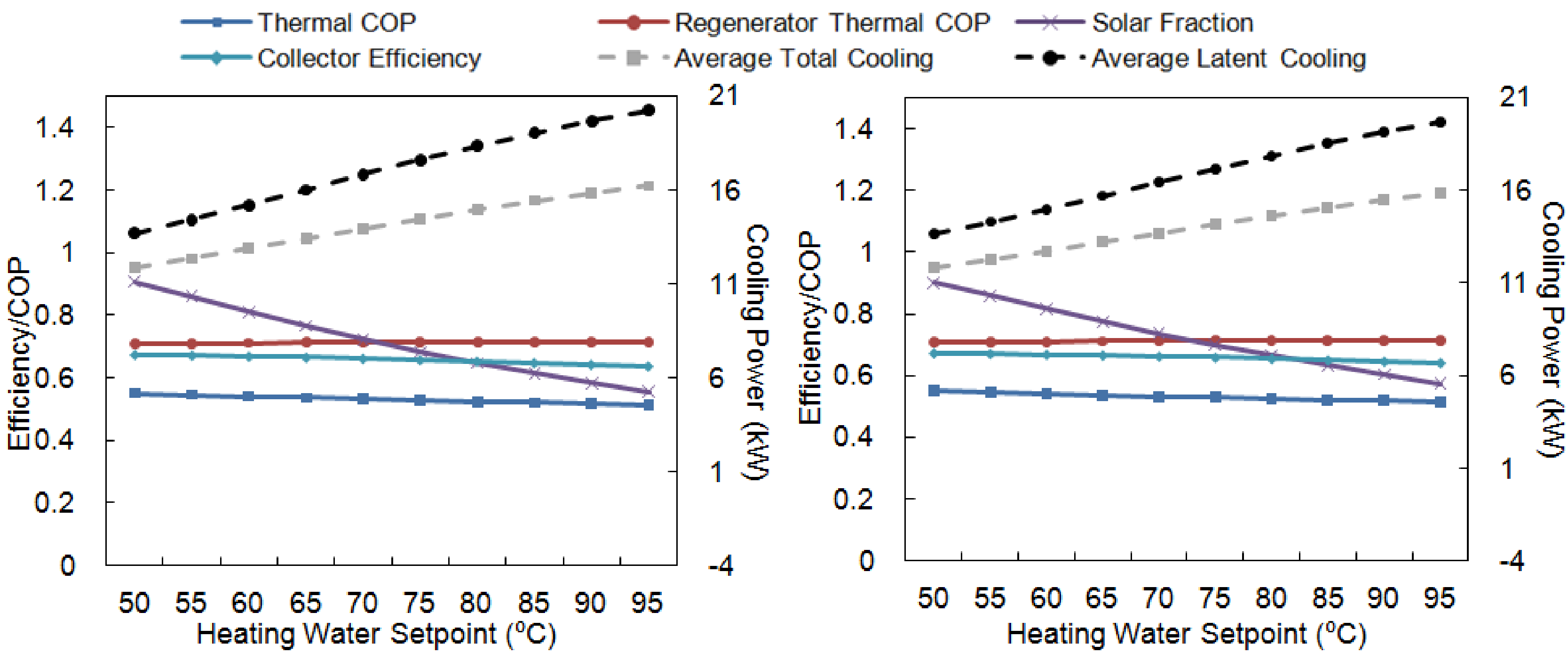


- TRNSYS simulations used to size array
- Large array increases cost, time in stagnation, pumping power
- Sized for 65% solar
- Storage implementation to increase SF and utilization

- Performance predicted for series (top) and parallel (bottom) boiler configurations



- Boiler setpoint temperature important system parameter
  - Increases cooling capacity and LDAC performance
  - Decreases collector efficiency

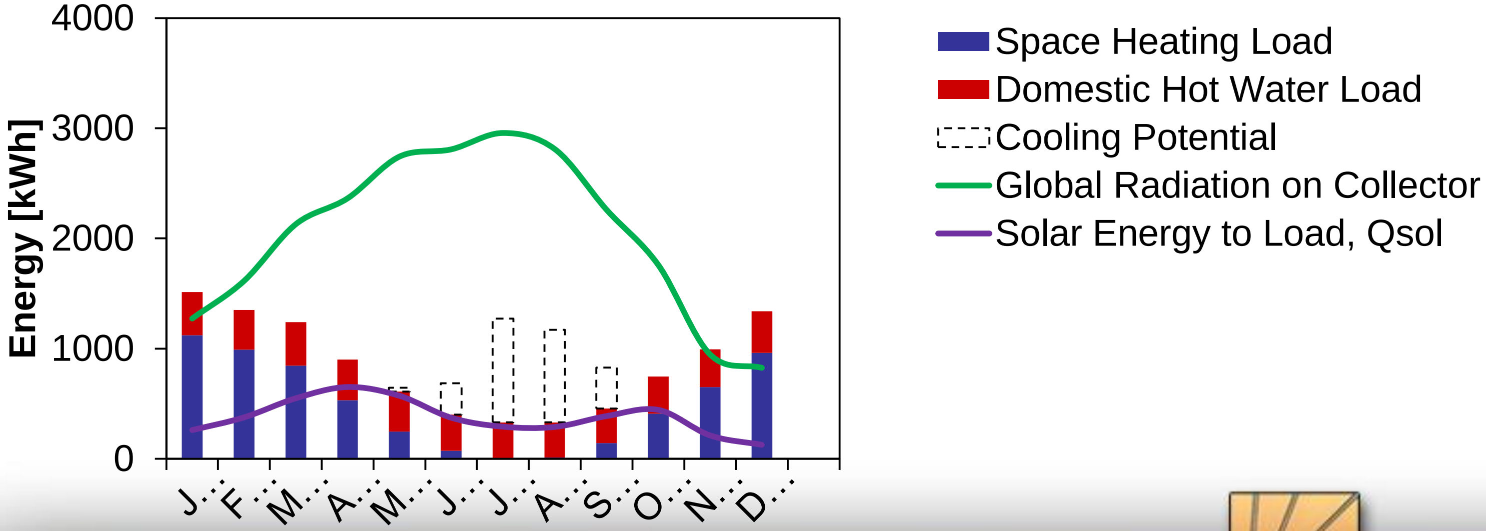


Conclusions

- Installation of 95m^2 evacuated tube solar array for low flow LDAC demonstration project
- TRNSYS simulations predict
  - 65% solar fraction
  - 65% collector efficiency based on absorber area (41% gross area)
  - Typical LDAC COP_T 0.4-.52
  - Average LDAC latent cooling power between 13 and 23kW (3.8-6.6 tons)

Future Work

- Improve system by replacing inefficient fans and pumps and integrating variable speed pump control
- Implement desiccant storage in demonstration project, use modelling to determine optimal storage configurations
- Monitor array to determine capacity for space heating and evaluate potential for solar combi-system



Natural Resources Canada

Solar Buildings Research Network

Queen's University Mechanical Engineering

AIL Research